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Research Article

Exploitation of hybrid vigour through diallel analysis in cucumber (*Cucumis sativus* L.)

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Abstract
A study to estimate heterosis of 45 F_1 hybrids obtained by crossing 10 diverse lines of cucumber was carried out at MVRS, AAU, Anand during 2015-16. Observations on characters *viz.*, fruit yield per plant, fruit length, fruit girth, fruit weight, number of primary branches per plant and number of fruits per plant were taken. Analysis of data revealed that all hybrids differed significantly within themselves for all the characters under study. The hybrid ACUS 13-60 x ACUS 9-51 exhibiting the highest heterotic effect over standard parent (GCU 1) for the characters, fruit yield per plant and number of fruits per plant can be exploited for commercial cultivation. For fruit length and number of primary branches per plant, none of the hybrids showed positive significant standard heterosis. The hybrid ACUS 9-50 x ACUS 9-51 and ACUS 13-58 x ACUS 13-60 exhibited the highest standard heterosis for fruit girth and fruit weight respectively.

Key words
Cucumber, F_1 hybrids, standard heterosis, heterotic effect

Introduction

Cucumber is an important cucurbitaceous vegetable grown in tropical and subtropical countries. According to Candolle (1886), centre of origin of cucumber is India and it is being cultivated over 3000 years in the country. The tender fruits of cucumber is generally consumed as salad and also used for pickling purpose. Fruits have cooling effect and good for patients suffering from jaundice, constipation and indigestion (Gopalakrishnan, 2007). Cucumber is a highly cross pollinated plant and domesticated types are monoecious or gynoecious. India being the centre of origin of cucumber possesses a vast range of genetic variability. However, it has not been fully assessed and utilized. The phenomenon of hybrid vigour or heterosis resulting from the cross between genotypically distinct parents forms an important means of crop improvement in cucumber. The cross pollinated nature of the crop and large number of seeds in a fruit provides ample scope for the utilization of hybrid vigour and its commercial exploitation in this crop. Hays and Jones (1916) were the first to report heterosis in cucumber. The adoption of hybrids and hybrid breeding programme in this crop is still in its infancy in India. Therefore, in view of the above and to make further studies in cucumber improvement, it was considered imperative to carry out a study to obtain information on heterosis for different characters in cucumber.

Materials and Methods

The present investigation was carried out during *kharif* 2016 at Main Vegetable Research Station, Anand Agricultural University, Anand. The crosses have been made during *kharif* 2015 and summer 2016 using ten diverse lines of cucumber (GCU 1, ACUS 9-44, ACUS 9-50, ACUS 13-58, ACUS 14-63, ACUS 13-60, ACUS 9-51, ACUS 14-62, ACUS 14-64 and ACUS 14-65) in half diallel fashion with parents (Griffing, 1956, Model I and Method II). The experimental material comprising 55 genotypes representing 45 hybrids and their 10 parents including a standard check (GCU 1) were evaluated in randomized complete block design with two replications.

Each experimental unit was represented by a single row accommodating ten plants with inter and intra row spacing of 1.5 and 1.0 meter, respectively. The recommended package of practices and plant protection measures are followed to raise a good crop. The biometric observations for plant growth, fruit yield and their component characters were recorded on randomly selected (tagged) five competitive plants in each experimental unit leaving border plants. The average values for all the traits were worked out for each experimental unit from the recorded data of the selected plants and subjected for statistical analyses. Heterosis in present investigation was calculated as heterobeltiosis (Fonseca and Patterson, 1968) and standard heterosis (Meredith and Bridge, 1972)

Results and Discussion

There was significant difference among the parental lines with respect to different characters studied *viz.*, fruit yield per plant, fruit length, fruit girth, fruit weight, number of primary branches per plant and number of fruits per plant. The hybrids also differed significantly for all the characters under study. The range of mean values of parents and hybrids and list of better performing parents and crosses for all the characters are presented in Table 1.The heterobeltiosis and standard heterosis for all the hybrids for characters under study are given in Table 2 and Table 3. For fruit yield per plant, the hybrid, ACUS 9-50 x ACUS 14-63 (105.14%) registered the highest heterobeltiosis and ACUS 13-60 x ACUS 9-51 (227.63%) exhibited the maximum standard heterosis. The results of present investigation revealed that the estimates of various heterotic effects were moderate to high in both the directions for fruit yield per plant. The results were congruent with the findings of Singh *et al.* (2010), Kushwaha *et al.* (2011), Singh *et al.* (2012), Airina *et al.* (2013) and Singh *et al*. (2015b).

The estimates of heterobeltiosis for fruit length ranged from -37.34 to 27.86%. The hybrid ACUS 9-50 x ACUS 14-65 (27.86%) registered the maximum heterobeltiosis. The estimates of heterobeltiosis were moderate in both the directions, while standard heterosis estimates were low in positive direction and moderate in negative direction. Majority of the F_1s depicted negative effect. The results are in agreement with the findings of Singh *et al*. (2010), Kushwaha *et al*. (2011), Singh *et al.* (2012), Airina *et al*. (2013) and Singh *et al*. (2015b).

For fruit girth, the estimates of heterobeltiosis ranged from -38.10 to 20.45%. The cross ACUS 9-44 x ACUS 14-64 (20.45%) exerted the maximum heterobeltiosis and the cross ACUS 9-50 x ACUS 9-51 (23.66%) depicted the highest standard heterosis. The results of present investigation revealed that the estimates of various heterotic effects were moderate in both the directions. The results corroborate with the findings of Kushwaha *et al*. (2011), Singh *et al*. (2015a) and Singh *et al*. (2015b).

Total 27 hybrids exhibited significant heterobeltiosis for fruit weight, of these seven had positive estimates. The hybrids ACUS 13-58 x ACUS 14-63 (30.39%) and ACUS 13-58 x ACUS 13-60 (38.04%) registered the highest heterobeltiosis and standard heterosis, respectively. The estimates of heterobeltiosis and standard heterosis for fruit weight were moderate in both the directions. The findings are in conformity with the reports of Singh *et al.* (1999), Kushwaha *et al*. (2011), Singh *et al.* (2012), Airina *et al*. (2013), Singh *et al*. (2015a) and Singh *et al*. (2016).

For number of primary branches per plant, the hybrid ACUS 14-62 x ACUS 14-65 (39.81%) exerted the highest positive heterobeltiotic effect. The estimates of standard heterosis ranged from -36.80 to 20.80%. Total 11 F_1s registered significant estimates, all of which had negative values. The heterotic effects for this character were moderate in both the directions, where most of the F_1s manifested negative effect. The findings of present study are in agreement with the reports of Singh *et al*. (1999) as they reported moderate estimate for heterobeltiosis in positive direction.

The cross ACUS 9-50 x ACUS 14-63 (131.71%) ranked first in heterobeltiosis for number of fruits per plant. Total 19 crosses depicted significant standard heterosis, of which, 15 exhibited positive effects. The cross ACUS 13-60 x ACUS 9-51 (184.02%) registered the maximum standard heterosis. The estimates of various heterotic effects were moderate to high in both the directions. The results are in accordance with the findings of Singh *et al.* (1999), Singh *et al.* (2010), Kushwaha *et al*. (2011), Airina *et al*. (2013) and Singh *et al*. (2015b).

In present study, moderate to high estimates of heterosis was observed for fruit yield per plant. Hence heterosis breeding is favoured for commercial purpose and the top heterotic hybrids ACUS 13-60 x ACUS 9-51, ACUS 13-60 x ACUS 14-62 and ACUS 13-60 x ACUS 14-65 may be used for commercial cultivation after evaluation over years and locations.

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Table 1. Range of mean performance of top parents and hybrids for different characters

Range	Fruit yield per plant (kg)	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Number of primary branches per plant	Number of fruits per plant
Range of mean values						
Parents	1.27 to 4.73	17.17 to 30.97	11.30 to 17.85	130.71 to 207.53	9.10 to 14.40	9.00 to 27.50
Hybrids	0.95 to 7.33	16.82 to 33.95	10.67 to 16.20	105.28 to 188.17	7.90 to 15.10	8.10 to 48.00
Top three parents*	P_6 (4.73) P_{10} (4.49) P_2 (3.63)	P_1 (30.97) P_8 (27.65) P_5 (27.42)	P_6 (17.85) P_3 (14.47) P_{10} (14.00)	P_1 (136.31) P_6 (207.53) P_7 (175.21)	P_3 (14.40) P_4 (13.80) P_1 (12.50)	P_{10} (27.50) P_2 (26.10) P_6 (22.50)
Top three hybrids*	P_6 x P_7 (7.33) P_6 x P_8 (6.03) P_6 x P_{10} (5.32)	P_3 x P_7 (33.95) P_1 x P_2 (30.88) P_1 x P_4 (30.73)	P_3 x P_7 (16.20) P_6 x P_9 (16.12) P_6 x P_{10} (15.92)	P_4 x P_6 (188.17) P_9 x P_{10} (187.89) P_4 x P_5 (186.82)	P_2 x P_6 (15.1) P_4 x P_{10} (14.9) P_5 x P_7 (14.7)	P_6 x P_7 (48.0) P_6 x P_8 (38.0) P_6 x P_9 (36.0)

P_1: GCU 1, P_2: ACUS 9-44, P_3: ACUS 9-50, P_4: ACUS 13-58, P_5: ACUS 14-63, P_6: ACUS 13-60, P_7: ACUS 9-51, P_8: ACUS 14-62, P_9: ACUS 14-64, P_{10}: ACUS 14-65
*According to mean performance

Table 2. Heterobeltiosis and standard heterosis for fruit yield per plant, fruit length and fruit girth

Hybrids	Fruit yield per plant		Fruit length		Fruit girth	
	HB	SH	HB	SH	HB	SH
P_1 x P_2	-9.56	46.79	-0.29	-0.31	-9.73**	-9.73
P_1 x P_3	61.47**	61.25	-6.70*	-6.71	-26.25**	-18.51**
P_1 x P_4	56.10**	55.89	-0.77	-0.79	-11.07**	-11.07
P_1 x P_5	36.92**	36.74	-13.88**	-13.9*	-8.00*	-4.31
P_1 x P_6	-38.66**	29.58	-24.46**	-24.47**	-18.49**	11.07
P_1 x P_7	68.51**	68.28	-11.14**	-11.15	10.31**	10.31
P_1 x P_8	38.12**	67.41	-8.72**	-8.73	-15.08**	-15.08*
P_1 x P_9	-36.75**	-9.06	-16.06**	-16.07**	-8.97**	-8.97
P_1 x P_{10}	-60.08**	-19.84	-11.14**	-11.15	2.96	10.04
P_2 x P_3	-51.31**	-20.98	13.66**	-7.36	-22.80**	-14.69*
P_2 x P_4	3.56	68.08	9.61**	-10.18	19.36**	14.12*
P_2 x P_5	-20.37**	29.24	-2.19	-13.41*	0.18	4.20
P_2 x P_6	-13.17**	83.44*	11.49**	-9.13	-25.35**	1.72
P_2 x P_7	-0.33	61.76	-6.13	-18.98**	18.46**	18.32**
P_2 x P_8	-10.14	45.85	2.62	-8.41	-7.16	-13.36*
P_2 x P_9	-8.65	48.26	10.10**	-10.26	20.45**	12.4*
P_2 x P_{10}	-34.64**	31.25	-23.76**	-37.86**	-2.86	3.82
P_3 x P_4	42.31**	-18.24	2.03	-16.40**	-16.93**	-8.21
P_3 x P_5	105.14**	46.99	9.75**	-2.84	-9.15**	0.38
P_3 x P_6	-50.93**	3.66	17.31**	-21.8**	-32.35**	-7.82
P_3 x P_7	7.40	-13.55	26.96**	9.59	11.92**	23.66**
P_3 x P_8	12.21	36.00	-23.47**	-31.70**	-10.81**	-1.45
P_3 x P_9	-26.87**	5.13	4.19	-17.77**	5.35	16.41**

P_3 x P_{10}	-31.68**	37.19	27.86**	-15.19**	-14.85**	-5.92
P_4 x P_5	66.73**	19.46	7.29*	-5.02	9.17**	13.55*
P_4 x P_6	-35.75**	35.74	11.62**	-8.54	-23.53**	4.20
P_4 x P_7	19.22	-4.04	1.07	-12.77*	-5.20	-5.31
P_4 x P_8	-35.14**	-21.38	-3.25	-13.65*	9.38**	4.58
P_4 x P_9	-70.42**	-57.48	-15.8**	-31.00**	15.37**	10.31
P_4 x P_{10}	-70.92**	-41.61	-1.12	-18.98**	-19.29**	-13.74*
P_5 x P_6	-34.48**	38.42	-0.82	-12.2*	-38.1**	-15.65**
P_5 x P_7	61.73**	30.18	-10.3**	-20.59**	-1.83	2.10
P_5 x P_8	-2.71	17.92	8.95**	-2.76	-8.44*	-4.77
P_5 x P_9	-53.28**	-32.83	-2.10	-13.33*	-19.63**	-16.41**
P_5 x P_{10}	-58.76**	-17.19	-8.02*	-18.58**	-21.32**	-15.92**
P_6 x P_7	55.09**	227.63**	-37.08**	-45.69**	-12.61**	19.08**
P_6 x P_8	27.59**	169.53**	-37.34**	-44.08**	-12.32**	19.47**
P_6 x P_9	12.21**	137.05**	-26.69**	-42.14**	-9.66**	23.09**
P_6 x P_{10}	12.50**	137.66**	-5.81	-37.22**	-10.78**	21.56**
P_7 x P_8	-2.76	17.86	-6.42	-16.48**	2.79	2.67
P_7 x P_9	22.47**	76.07	-2.11	-15.51**	4.13	4.01
P_7 x P_{10}	-46.80**	6.83	-15.58**	-27.13**	-6.96*	-0.57
P_8 x P_9	-29.67**	1.12	8.50**	-3.16	0.61	-6.30
P_8 x P_{10}	-30.70**	39.15	-10.49**	-20.11**	12.68**	20.42**
P_9 x P_{10}	-50.64**	-0.89	6.34	-16.07**	5.71	12.98*
SE	0.41	0.41	1.82	1.82	0.91	0.91
CD at 5%	0.80	0.80	3.56	3.56	1.78	1.78

* Significant at 5 per cent probability level, ** Significant at 1 per cent probability level

Table 3. Heterobeltiosis and standard heterosis for fruit weight, number of primary branches per plant and number of fruits per plant

Hybrids	Fruit weight		Number of primary branches per plant		Number of fruits per plant	
	HB	SH	HB	SH	HB	SH
P_1 x P_2	11.26	14.18	6.40	6.40	-18.39**	26.04
P_1 x P_3	-7.48	-7.49	-43.75**	-35.2**	68.05**	68.05**
P_1 x P_4	-5.55	-0.72	-41.30**	-35.20**	50.89**	50.89**
P_1 x P_5	-5.51	-5.51	-35.20**	-35.20**	42.01**	42.01**
P_1 x P_6	-31.19**	4.75	-36.80**	-36.80**	-10.67*	18.93
P_1 x P_7	-5.31	21.71	-28.80**	-28.80*	33.14**	33.14*
P_1 x P_8	18.70*	20.17	-28.80**	-28.80*	14.57*	34.91*
P_1 x P_9	-1.06	13.94	-29.60**	-29.60*	-33.82**	-20.12
P_1 x P_{10}	-15.57*	0.52	-22.40**	-22.40	-52.00**	-21.89
P_2 x P_3	-7.89	-5.48	-11.11	2.40	-46.74**	-17.75
P_2 x P_4	21.88**	28.10	-19.57**	-11.20	-18.39**	26.04
P_2 x P_5	15.99*	19.03	-13.01	-14.40	-31.03**	6.51
P_2 x P_6	-42.53**	-12.51	22.76**	20.80	33.72**	106.51**

P_2 x P_7	-8.73	17.32	-2.44	-4.00	-11.88**	36.09**
P_2 x P_8	20.07**	23.22	11.38	9.60	-29.12**	9.47
P_2 x P_9	-1.45	13.49	-13.82*	-15.20	-18.39**	26.04
P_2 x P_{10}	-15.85*	0.18	-33.33**	-34.40*	-22.55**	26.04
P_3 x P_4	-22.12**	-18.15	-22.92**	-11.20	69.70**	-0.59
P_3 x P_5	-14.04	-17.15	-11.81*	1.60	131.71**	68.64**
P_3 x P_6	-37.98**	-5.58	1.39	16.80	-18.67**	8.28
P_3 x P_7	-21.15**	1.35	-32.64**	-22.40	38.24**	-16.57
P_3 x P_8	0.11	1.35	-25.69**	-14.40	11.56*	31.36*
P_3 x P_9	-12.12	1.20	-20.83**	-8.80	-17.65**	-0.59
P_3 x P_{10}	-21.58**	-6.64	-6.25	8.00	-14.18**	39.64**
P_4 x P_5	30.39**	37.05*	-7.25	2.40	14.63	-16.57
P_4 x P_6	-9.33	38.04*	-5.80	4.00	-28.44**	-4.73
P_4 x P_7	-11.86*	13.29	-25.36**	-17.60	38.24**	-16.57
P_4 x P_8	-10.94	-6.39	-23.91**	-16.00	-29.65**	-17.16
P_4 x P_9	-23.13**	-11.48	2.90	13.60	-60.29**	-52.07**
P_4 x P_{10}	-20.81**	-5.73	7.97	19.20	-64.00**	-41.42**
P_5 x P_6	-39.33**	-7.64	25.00**	16.00	10.67*	47.34**
P_5 x P_7	-19.88**	2.98	24.58**	17.60	70.73**	24.26
P_5 x P_8	12.27	13.65	18.42*	8.00	-12.56*	2.96
P_5 x P_9	-32.94**	-22.77	25.44**	14.40	-29.41**	-14.79
P_5 x P_{10}	-22.18**	-7.36	10.53	0.80	-46.55**	-13.02
P_6 x P_7	-25.92**	12.78	-12.71	-17.60	113.33**	184.02**
P_6 x P_8	-22.87**	17.41	-17.24*	-23.20	68.89**	124.85**
P_6 x P_9	-31.11**	4.87	-31.03**	-36.00**	64.00**	118.34**
P_6 x P_{10}	-23.12**	17.03	-11.21	-17.60	20.00**	95.27**
P_7 x P_8	-2.37	25.48	-16.95*	-21.60	-23.12**	-9.47
P_7 x P_9	3.44	32.95*	-3.39	-8.80	4.90	26.63
P_7 x P_{10}	-24.06**	-2.40	-27.12**	-31.20*	-35.27**	5.33
P_8 x P_9	16.36*	34.00*	-12.62	-28.00*	-41.18**	-28.99*
P_8 x P_{10}	0.69	19.87	39.81**	15.20	-31.64**	11.24
P_9 x P_{10}	15.78*	37.83*	14.85	-0.72	-56.36**	-28.99*
SE	20.27	20.27	1.70	1.70	2.32	2.32
CD at 5%	39.72	39.72	3.33	3.33	4.54	4.54

* Significant at 5 per cent probability level, ** Significant at 1 per cent probability level